DESIGN AND IMPLEMENTATION OF MULTIPLE USER MOBILE ROBOT FOLLOWING SYSTEM

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A project report submitted in partial
fulfilment of the requirement for the award of the
Master of Electrical Engineering

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JUNE 2015

ABSTRACT

Recently automation product for intelligent robot is increasingly getting very common. By the help of intelligent robot technologies that increased comfort, greater safety and security, life has been becoming easier [1]. With this system, mobile robot can be controlled from any target. It is desirable in many applications for a mobile robot to track and follow a person. The purpose of this thesis is to detail the design and implementation of a mobile robot following system through the use of beacons and remote control encoder decoder. This project entailed the design and construction of a mobile robot with the capability of determining its location in reference to know reference points and correct address. The implementation involved the use of ultrasound to determine the distance between the robot and known reference points and infrared decoder and decoder to determine the correct leader. From the distance, the Cartesian coordinates for the robot's location along the horizontal plane where determined. The produced robot was capable of navigating within a 2m by 2m square area successfully. Possible source of error can be attributing to round of error due to conversion from floating point to integer as well as errors within the reflection of ultrasound frequency used to synchronize beacon transmission.

ABSTRAK

Pada masa ini produk automasi untuk robot pintar semakin mendapat sambutan. Dengan bantuan teknologi robot pintar yang dapat meningkatkan keselesaan, keselamatan dan keselamatan , kehidupan telah menjadi lebih mudah [1]. Dengan sistem ini, robot mudah alih dapat dikawal dari mana-mana sasaran. Ia adalah wajar kerana dalam banyak aplikasi, robot mudah alih dapat mengesan dan mengikuti seseorang. Tujuan tesis ini adalah untuk menerangkan dengan lebih jelas tentang reka bentuk dan pelaksanaan sistem ikutan robot mudah alih dengan menggunakan 'beacon' dan pengkod serta penyahkod kawalan jauh. Projek ini melibatkan reka bentuk dan pembinaan sebuah robot mudah alih dengan keupayaan menentukan lokasinya dengan merujuk titik rujukan dan alamat yang betul. Pelaksanaan ini melibatkan penggunaan isyarat ultrasonik untuk menentukan jarak antara robot dan rujukan yang dikenalpasti untuk diikuti dan pengkod serta penyahkod inframerah untuk menentukan bahawa sasaran untuk diikuti adalah betul. Dari jarak tersebut, koordinat Cartesian untuk lokasi robot sepanjang satah mendatar dapat ditentukan. Robot yang dihasilkan mampu bergerak dalam kawasan 2m x 2m dengan jayanya. Kesalahan yang mungkin berlaku adalah disebabkan oleh penukaran nilai titik perpuluhan ke nilai integer, juga boleh disebabkan oleh pantulan frekuensi ultrasound yang digunakan untuk menyegerakkan isyarat pengeluar dari 'beacon' .

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LIST OF ABBREVIATION

A	Ampere
B	Binary
CPU	Central Processing Unit
D	Decimal
GPS	Global Positioning System
I	Current
IFC	Interface Free Card
LED	Light Emitting Diode
MC	Microcontroller
PC	Personal Computer
R	Resistance
RF	Radio Frequency
RAM	Random Access Memory
ROM	Read Only Memory
V	Volt
H	Hexadecimal
AC	Alternating Current
DC	Direct Current
PIC	Programmable Interface Controller
PID	Proportional Integral Derivative
IFC	Interface free Card
TOF	Time of Flight

IR	Infrared
IRR	Infrared Receiver
TX	Transmitter
RX	Receiver

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CHAPTER I

INTRODUCTION

1.1 Project Overview

This paper presents the result of efforts to design and implement a mobile robot following system in part to fulfill the requirement for the UTHM. The Mobile robot following system incorporates the use of encoder and decoder device with ultrasonic sensors as a following system. This project is a two-semester endeavor and this paper presents the hardware and software design and a detail description of testing and building of the system. This lays the framework for the rest of the robotics development platform while thoroughly exploring the behavior of a human following robot system.

1.2 Introduction

In recent years, mobile robot has become autonomous enough to suite the application in our life. Navigation within local environments may be comprised of various methods however this report addresses the use of navigation relative to beacons. Navigation relative to beacons utilizes the distance or direction between the robot and beacon utilizes the distance or direction between the mobile robot and several beacons in order to determine the position of the mobile robot relative to the beacon. If the beacon positions are known, the robot will be able to recognize its own position within its operational environment. Active beacon has been used in this project. In order to determine location relative to beacons the robot may utilize either triangulation or trialation. Triangulation refers to the use of the angle measurements between the robot and the various beacons while trialation uses distance measurements. An active beacon is a system where the beacon transmits its location, through a signal, to the robot. This usually consists of ultrasound or radio transmitters, which are synchronized either by a single beacon controller or by the robot itself. The mobile robot detects the transmissions of these beacons and uses either the distance (calculated through DTOF measurements) or angle measurements to determine its position. An IFC Mobile Robot with an additional encoder and decoder with ultrasonic positioning system have been adopted to implement specific human-following system. The first stage is human positioning. Encoded signals and ultrasonic signal are transmitted from beacon located on a specially made casing, which the target leader wears. The signals will be received by ultrasonic receivers and IR decoder located on the Mobile Robot, this coded address can be change in the controller to match it with the transmitter, five(5) ultrasonic sensors will be use to control the robot algorithm. Finally, with the readings from the ultrasonic positioning system, a potential field based motion algorithm is formed [1]**.** Basically, the leader in leader/follower behavior is the target that is followed by the other robot (follower). The leader (target) can be either human or robot. The follower, which is a robot, need to follow the leader autonomously. The task of this behavior is called task following. When a follower robot performs a task following, the most important thing for the follower is to be able to obtain the position of the leader. The follower must be able to obtain its current position relative to the target before it makes decision on how to follow the target. “Localization” or knowledge of its current location is calculated by one or more means, using sensors such as motor encoder, vision, laser or sonar sensors. There are many vision systems being built to track and follow the target effectively. The method can be seen in [11], [12] and [13].

1.3 **Problem Statement:**

The idea to invents and develops the Mobile Robot Following System begin when Few applications of cooperative robotics have been reported, and supporting theory is still in its formative stages [14]. One of the main tasks for cooperative wheeled mobilerobots [15] is the object (target) following task, which usually represents to follow another robot. Also, the following task is important for the wheeled mobile robots in [9], [10] and the target can be static or a dynamic object. There are many problems arise when designing a robot to perform a following task. These problems include robot may looses or hits the target being followed. Besides, the robot may also choose not to follow the desired object and goes after another detected object from the environment in a dynamic environment. Current human-tracking mobile robots also are not capable of operating in unstructured environments. Because several main approaches, such as vision and infrared sensors, are not fully reliable in all situations and it cannot give a condition to differentiate which target to follow, it is necessary to explore other methods. The main objective of this research is to investigate the feasibility of developing an intelligent human-following robot system so that it can support human in everyday life by interacting with specific human. In this research the positioning system using a encoder/decoder with ultrasonic will be consider.

1.4 Objective

The main objective is to design and implement the mobile robot following system using an IR encoder/decoder/ and ultrasonic beacon positioning system, equipped on the IFC mobile robot. There are 3 main objectives, at least to be achieved during the time frame of the project as follows:-

1. To design and construct an autonomous following robot system.
2. To integrate the concept of selected leader/follower behavior.
3. To improve the capability of the mobile robot in performing the following task smoothly by Programming a PID controller in the system.

1.5 Scope of work

The project will be done by limiting the scopes into four (4). The scopes are as follows:

1. The working model will only use IR encoder/decoder channel.

2. This mobile robot can be only move in linear platform.

3. Detection of target distance is 0 to 3 meters.

4. Mobile Robot is control by using PIC microcontroller and program the PIC via MPLAB programming software with C-18 compiler.

1.6 Flow chart

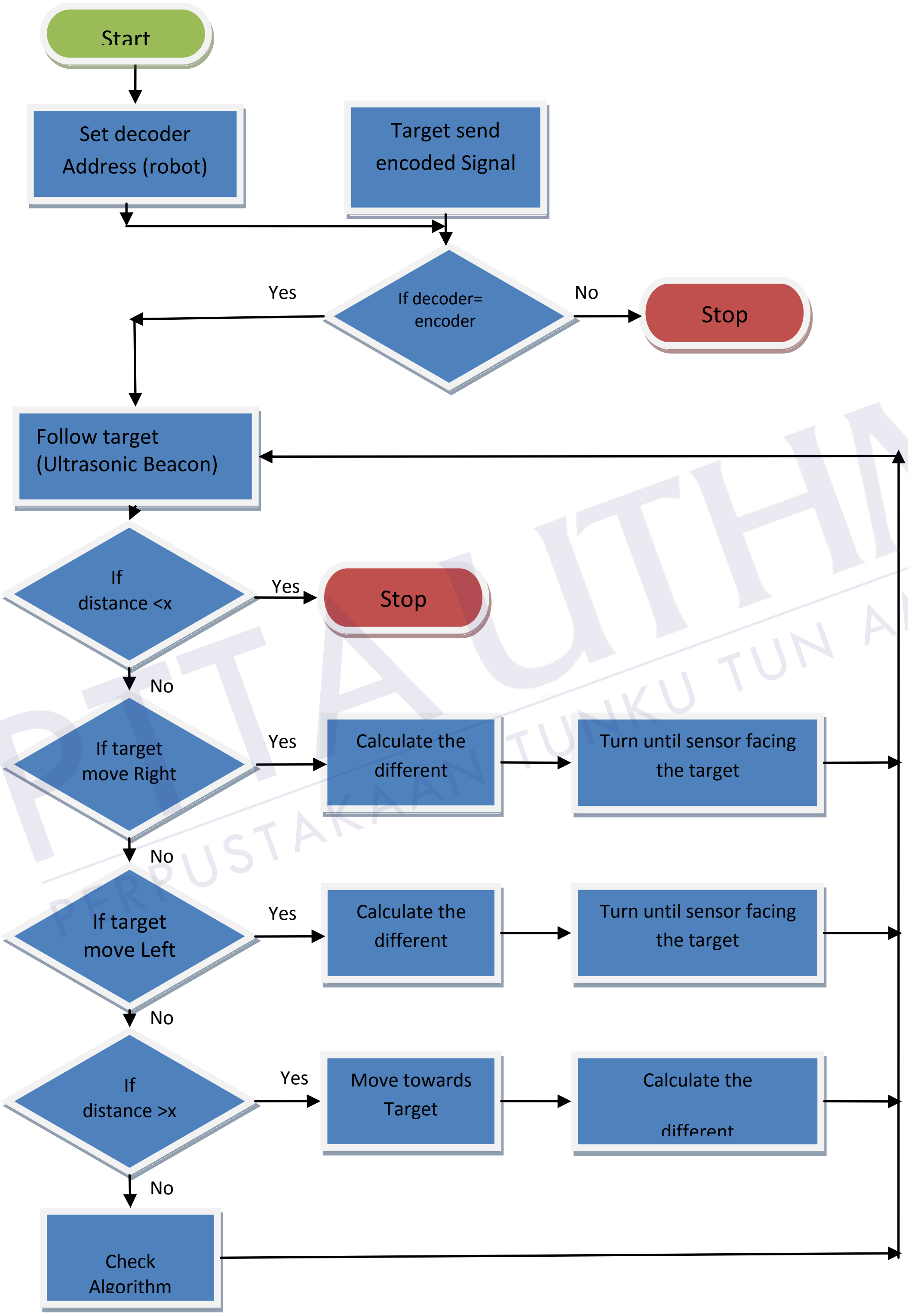

Figure 1.1 : Project Flow Chart

The flow chart of the project is shown in figure 1.1, From the flowchart, IFC Mobile robot must be set for certain channel address. First the target must send channel data (encode) through IR frequency carrier that is 38Khz, the receiver at the Mobile Robot will decode the data, if the address code did not match it will stop, and when it find its match address code, the mobile robot will follow the target that have the same channel with it by calculating the different from ultrasonic TX and ultrasonic RX . When it find an obstacle it will try to find the target according its algorithm program. This Mobile robot will be equipped with five (5) 40Khz ultrasonic distance sensor that will check the status of the target movement itself. The Ultrasonic sensor will be use to determine whether the target move left, right or stop.

CHAPTER 2

LITERATURE REVIEW

2.1 Background

A literature review was done to identify the main problems those are affect on this project. For this research it is necessary to identify which part are related to the project. This chapter will present background information about several position systems that are conventionally used for autonomous robot following system and review some of the robots that were built to perform the task following. Position and orientation information can be relative or global. The knowledge of the global or relative orientation and position of a robot provides the ability to create advanced control strategies and can be used to improve the overall perception of a following environment.

2.2 Literature related to area of study

2.2.1 Sensor Based Approach

A non-vision based approach uses several kinds of rangefinders, such as sonar sensors, infrared sensors, and others. Each rangefinder on the robot can determine the distance between the nearest object and the rangefinder itself. Because the robot is not able to distinguish between object and target person, this approach can only be adopted to implement either obstacle avoidance when regarding all the objects as obstacles or person-tracking when the target person is always the nearest object to the robot without any obstacle in between [1-10].

2.2.2. Transmitter and receiver Based Approach

Using a transmitter and receiver approach, the transmitters located on the target person transmit signals, such as ultrasonic waves or blinking LED. The receivers located on the mobile robot receive these signals. After computing the distance and the angle of the target from those signals, the robot knows where to move in order to turn itself toward the target person and decrease the distance in between. In [1], [5], [6] a transmitter and receiver based approaches have been discussed.

2.2.3 Following System Using Infrared based Approach

The main method in following system is potential field method, where the follower was "attracted" to the target and was "pushed away" from the obstacles [7]. Using an Infrared approach, IR receiver is installed inside a black hollow cylinder , the IR receiver can receive the signal emitted from the IR transmitter only when the transmitter is placed in front and along with the axis of the cylinder, which confirms the directional property of the light. The detection range of the receiver can be adjusted by placing the side walls around the receiver. One of the simplest methods to deploy several receivers to cover the front 180-degree detection range is to equally divide the detection range by the number of the utilized receivers, just like slicing the cake [1] as shown in figure 2.1 and 2.2.

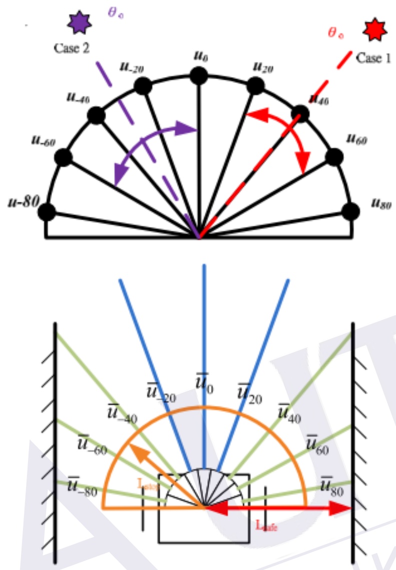

Figure 2.1 Configuration of nine ultrasonic range finders installed on the follower

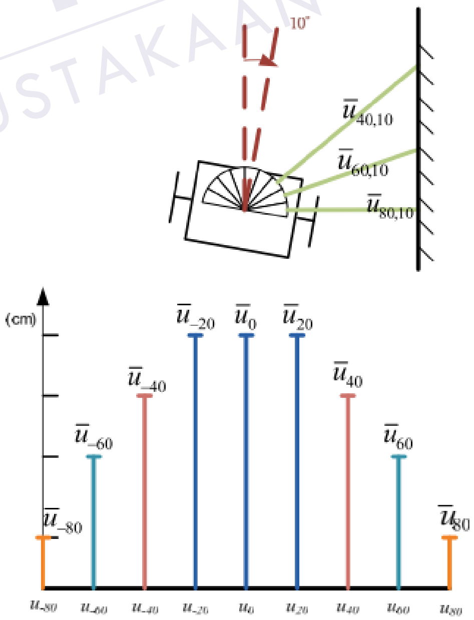

Figure 2.2 :Configuration where the threshold configuration where the threshold determined and the values ofhe thresholds

2.2.4 Following System Using Blinking LED Devices

This approach requires equipping the target person with two infrared LED devices with fixed distance between them and using a camera on the robot to detect the two devices. This is similar to the vision-based approach. The main difference is that the signals from infrared LED devices should be firmer and not affected by the disturbance in the environment, as long as they are not blocked by any obstacle. The camera is able to rotate to keep the target person in the middle of the image. By computing the distance between two LED lights and the deviation of the two lights from the central vertical axis in the image, the range and the bearing of the target person can be obtained respectively by the robot [8] as shown in figure 2.3.

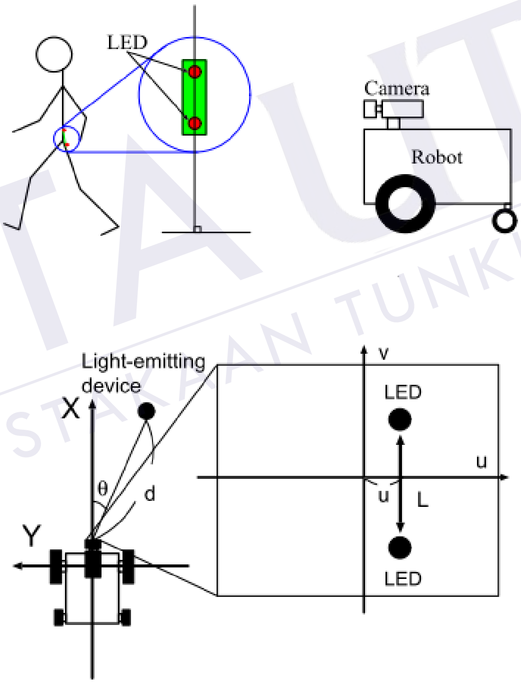

Figure 2.3: The robot follows the human using a camera and the image of LEDs obtained from camera mounted on the robot.

2.2.5. Following System Using an Ultrasonic Positioning System

This approach is to equipped the ultrasonic transmitters on the target person and the receivers on the robot. By computing the time interval between transmitting and receiving the ultrasonic signal, the distance between the target person and the robot will be determined. The angle can also be computed from the time delay between several receivers. These approaches are straight-forward for person-tracking, but they are not suitable when there are obstacles between the target person and the robot. The detection of obstacles will be a problem using these approaches. Without any additional mechanism, the robot is not able to implement obstacle avoidance. [2]

2.2.6 Following System using Intelligent Space Approach

The intelligent space approach [9], [10] utilizes several sensors, such as visual or non-visual sensors that are located in the environment to detect both the robot and the target person. Therefore, the position information of the robot and target person will be in the global coordinate and determined by the sensors in the intelligent space. From the relative positions of the robot and the target person, the robot motion will be planned by this intelligent space and controlled through the network. However, the desired approach in this research is to design an autonomous robot that implements tasks in unstructured environments. This approach then becomes unsuitable although it well function.

2.2.7 Following Systems Using Combined/Multi-Mode Approach

A combined/multi-modal approach is made of a combination of several approaches. It is able to gather the advantages of each single approach. This is also the key subject in this thesis. By using an ultrasonic positioning system along with the IR decoders, this research combines the transmitter-and-receiver based approach with the non-vision based approach. A suitable algorithm also will be designed to adapt the robot to several situations that may happen in the implementation of person-tracking. The robot can then accomplish the person-tracking tasks, which include person-following and obstacle avoidance in unstructured environments [6].

2.2.8 Microcontroller

Like most computers, microcontrollers (MCs) are simply general-purpose instruction executors. Like the computer, the effectiveness of an MC depends amongst other things upon the program of instructions provided to it and hence the skill of the programmer. A program is a series of instructions that step the computer through a sequence of simple data manipulations to accomplish useful tasks. In all cases MCs are small stand-alone computer systems designed for the purpose of control whereas a personal computer (PC) is primarily designed to process large amounts of data quickly. An MC has all of the components on a single chip, such as CPU, RAM, ROM, inputs and outputs. A microprocessor is simply a CPU and needs the RAM, ROM, inputs and outputs to be added to the system. Shown in figure 2.4.

Following are the reasons why microcontrollers are incorporated in this control systems:

a. *Cost:* Microcontrollers with the supplemantary circuit components are much cheaper than a computer with an analog and digital I/O.

b. *Size and Weight:* Microcontrollers are compact and light compared to computers.

c. *Simple applications:* If the application requires very few number of I/O and the code is relatively small, which do not require extended amount of memory and a simple LCD display is sufficient as a user interface, a microcontroller would be suitable for this application.

d. *Reliability:* Since the architecture is much simpler than a computer it is less likely to fail.

e. *Speed:* All the components on the microcontroller are located on a singe piece of silicon. Hence, the applications run much faster than it does on a computer.

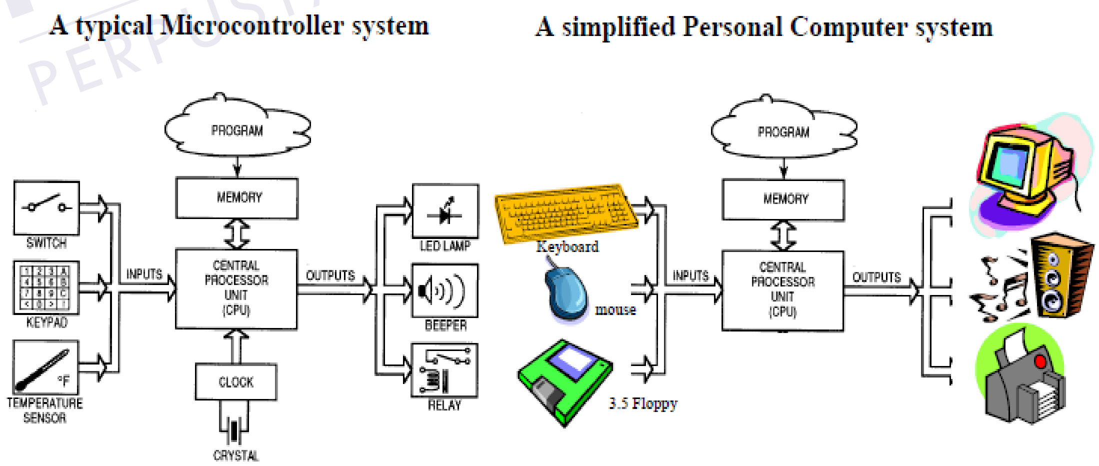

Figure 2.4: Typical structures of a microcontroller and personal computer system

2.2.9 GPS

Global Position Systems are widely becoming the position system of choice for autonomous navigation. This technology allows for an agent to determine its location using broadcasted signals from satellites overhead. The Global Positioning System associated with the United States is maintained by the Department of Defense to providea positioning service for use by the US military [17]. Since its creation, the service hasbeen used for commercial purposes such as nautical, aeronautical, and ground based navigation, and land surveying. The current US based GPS satellite constellation system consists of a 24-satellite system. The number of satellites for this system can vary due to satellites being taken in and out of service. Other countries are leading efforts to developalternative satellite systems for their own GPS systems. A similar GPS systems is the GLONASS constructed by Russia [17]. Each satellite maintains its own specific orbit and circumnavigates earth once every 12 hours. The orbit of each satellite is timed and coordinated so that five to eight satellites are above the horizon of any location on the surface of earth at any time. Figure 2.5 illustrates the manner by which an autonomous vehicle determines its' position using GPS.

Fig. 2.5: Global Position System Illustration

2.2.9.1 Position Solution

A GPS receiver calculates position by first receiving the microwave RF signals broadcast by each visible satellite [17]. The signals broadcasted by the satellites are complex high frequency signals with encoded binary information. The encoded binary data contains a large amount of information but mainly contains information about the time that the data was sent and location of the satellite in orbit. The GPS receiver processes this information to solve for its position and current time.

2.2.9.2 Accuracy and Update Rate

GPS receivers typically provide position solutions at 1Hz but GPS receivers can be purchased that output position solutions up to 20Hz. The accuracy of a commercial GPS system without any augmentation is approximately 15 meters [19]. Differential GPS is an alternative method by which GPS signals from multiple receivers can be used to obtain higher accuracy position solutions. Differential GPS operates by placing a specialized GPS receiver in a known location and measuring the errors in the position solution and the associated satellite data. The information is then broadcast in the form of correction data so that other GPS receivers in the area can calculate a more accurate position solution. This system is based on the fact that there are inherent delays as the satellite signals are transmitted through the atmosphere. Localized atmospheric conditions cause the satellite signals within that area to have the same delays. By calculating and broadcasting the correction values for each visible satellite the differential GPS system can attain accuracy from 1mm to 1cm [17]. Recently a new type of GPS correction system has been integrated so that a land based correction signal is not required to improve position solutions. The Wide Area Augmentation System sends localized correction signals from orbiting satellites [18].

Currently this system only covers most of North America. This type of system has been used in research and position solutions with errors of less than three meters have been observed.

2.2.10 Beacon Based Position Systems

This type of position system is based on determining the position of a mobile agent by actively or passively communicating with devices in the environment. These devices can range from RF and ultrasonic transmitters to signal reflectors similar to those used for Radar. This system typically relies on knowledge of beacon positions apriority. With an accurate locations of the various beacons in the environment, a mobile agent can calculate its' position and orientation by using the perceived geometric relationship between the beacons. Shown below in Figure 2.6 is an illustration of a typical beacon configuration for determining the position and orientation of a mobile agent. GPS is a form of space based beacon position system. Typically an autonomous agent determines the distances and or angles from its position and orientation to the specified beacon and combines this information with that of other beacons. Beacon based position systems can be used for many types of navigation but have limitations dependent on their configurations. Historically, aircraft used to perform navigation by receiving land based beacon signals [16]. Each beacon had a specific broadcast frequency. An aircraft would tune into the broadcast frequencies of the beacons located at the departure and arrival destinations. Using the information derived from relative angles of the beacons, an aircraft could maintain a direct flight path. This system caused problems due to the constraint and inefficiency of direct flight paths. This system also required large numbers of beacons to be placed across the country to accommodate typical flight paths. The system also presented problems when traveling across large oceans where intermediate beacons could not be placed.

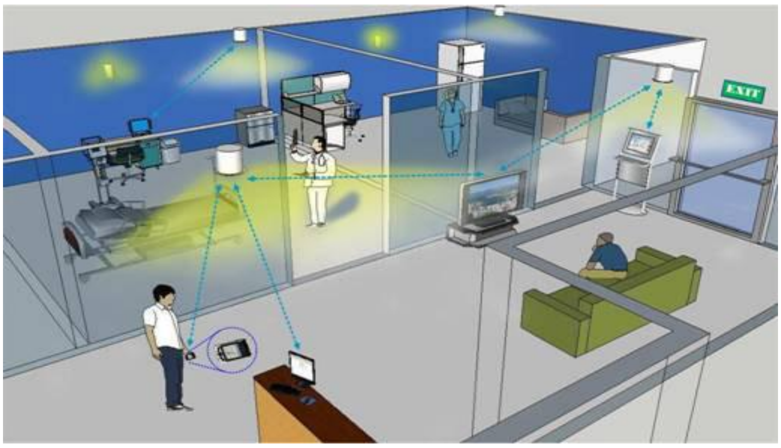

Fig. 2.6: Beacon Based Positioning for office equipment

CHAPTER 3

METHODOLOGY

3.1 Background

This part of section is mainly to shown the flow of methods used in this project. Predetermine the steps involved in any project can predict on the instruments, procedures, results, cost and others. This is very important to researcher because, time frames of dividing the research part can save time and deliver optimum results. The method in form of flow chart that involved in this project is discussed as shown in figure 3.1.:

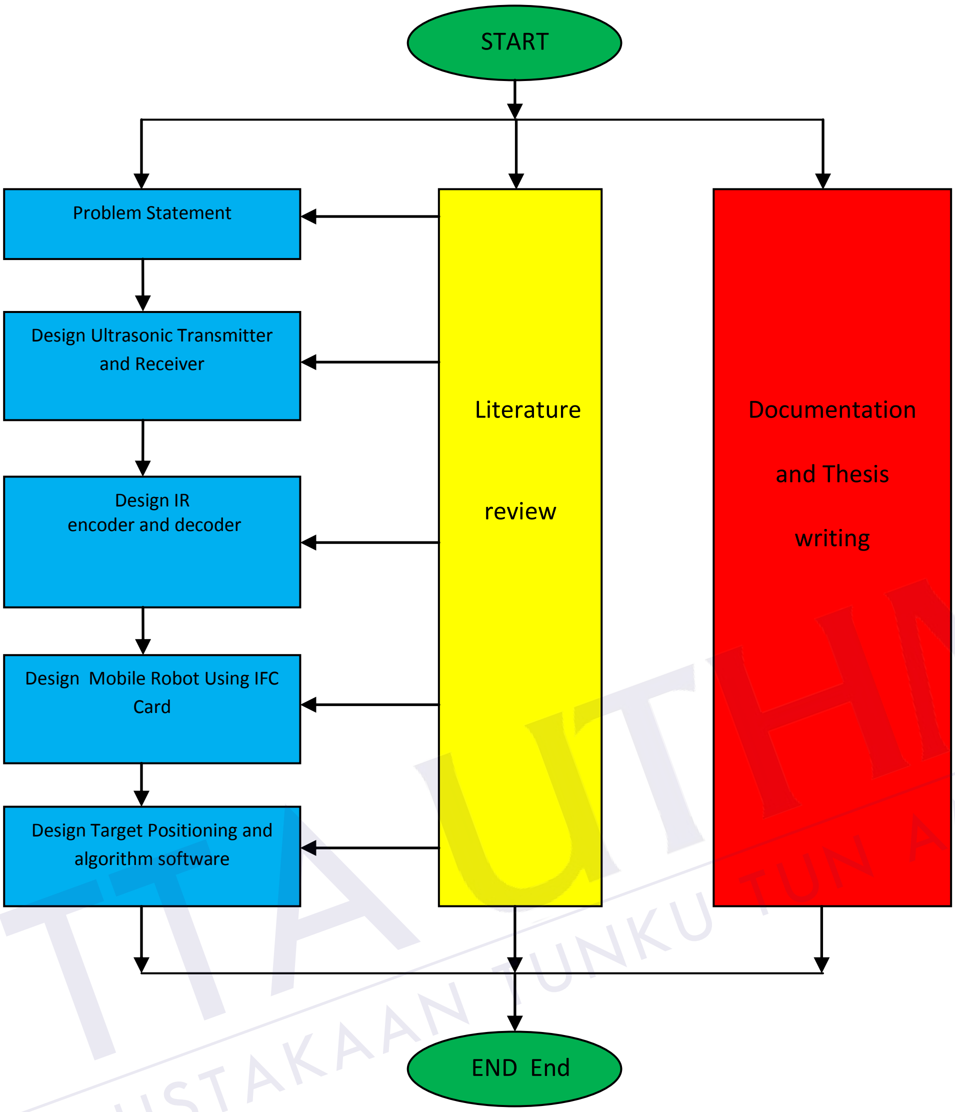

Figure 3.1: The flow chart of project implementation

3.2 Ultrasonic, encoder and detector :

3.2.1 Ultrasonic principle:

Ultrasonic sensors emit short, high-frequency sound pulses at regular intervals. These propagate in the air at the velocity of sound. If they strike an object, then they are reflected back as echo signals to the sensor, which itself computes the distance to the target based on the time-span between emitting the signal and receiving the echo, refer to figure 3.2.

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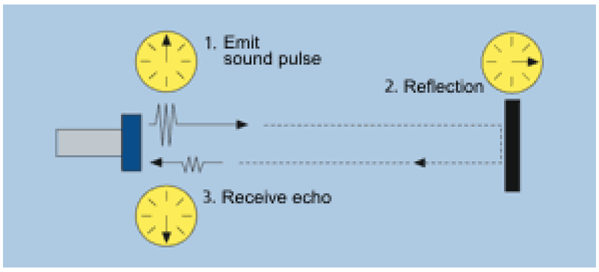


Figure 3.2 Ultrasonic principle

As the distance to an object is determined by measuring the time of flight (TOF) and not by the intensity of the sound, ultrasonic sensors are excellent at suppressing background interference. Virtually all materials which reflect sound can be detected, regardless of their color. Even transparent materials or thin foils represent no problem for an ultrasonic sensor. Ultrasonic sensors are suitable for target distances from 20 mm to 10 m and as they measure the time of flight they can ascertain a measurement with pinpoint accuracy. Some of ultrasonic sensors can even resolve the signal to an accuracy of 0.025 mm. Ultrasonic sensors can see through dust-laden air and ink mists. Even thin deposits on the sensor membrane do not impair its function. Sensors with a blind zone of only 20 mm and an extremely thin beam spread are making entirely new applications possible today. Fill level measurement in wells of micro titer plates and test tubes, as well as the detection of small bottles in the packaging industry, can be implemented with ease. Even thin wires are reliably detected. Sound is our inner ear's ability to detect the variations in air pressure caused by vibration. The rate of these variations determines the pitch of the tone. Higher frequency tones result in higher pitch sounds and lower frequency tones result in lower pitch tones. Most people can hear tones that range from 20 Hz, which is very low pitch, to 20 kHz, which is very high pitch. Subsonic is sound with frequencies below 20 Hz, and ultrasonic is sound with frequencies above 20 kHz. Since the sensor's are at 40 kHz, they are definitely ultrasonic, and not audible as shown in figure 3.3 and 3.4.

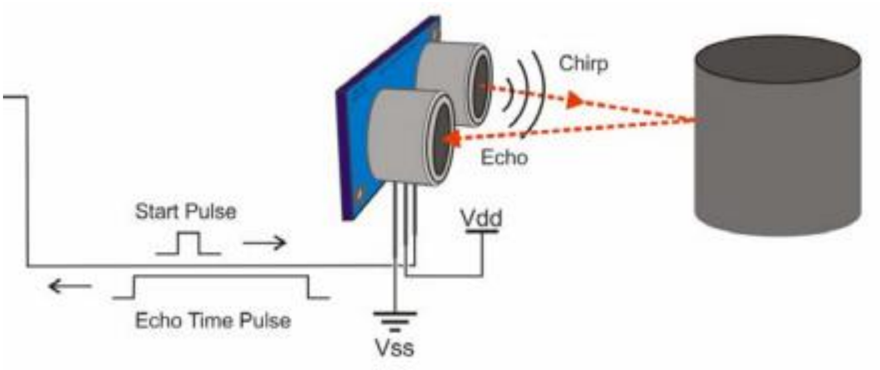
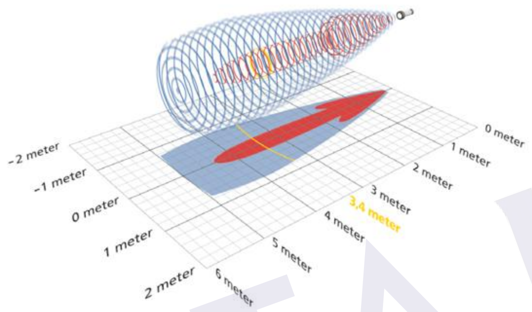
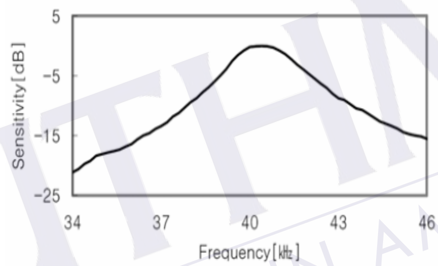


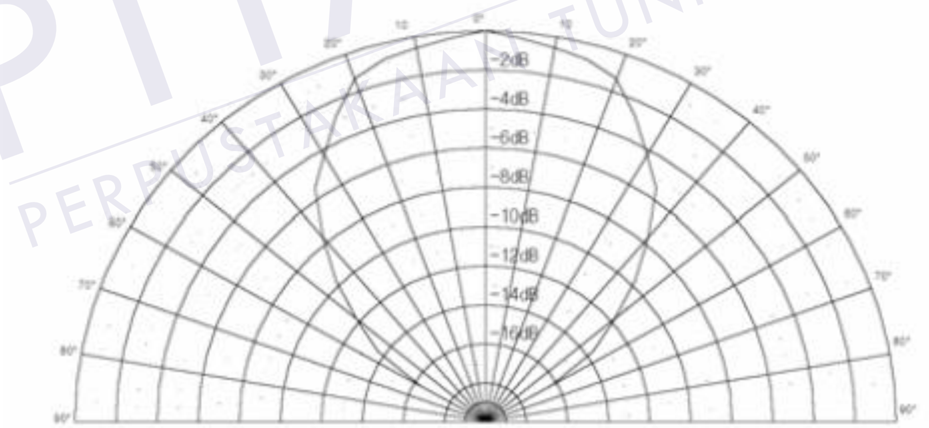
Figure 3.3 Ultrasonic Tx and Rx Principles



(a)



(b)



(c)

Figure 3.4 (a) Ultrasonic wave propagation (b)ultrasonic sensor frequency, (c) ultrasonic sensor directivity

3.2.2 Encoder design:

An encoder is a circuit that accepts an active level on one of its inputs, representing digit, such as a decimal or octal digits, and converts it to a coded output such as BCD or binary. Encoders can also be devised to encode various symbols and alphabetic characters. The process of converting from familiar symbols or numbers to a coded format is called encoding. Figure 3,5 shows the IR encoder.

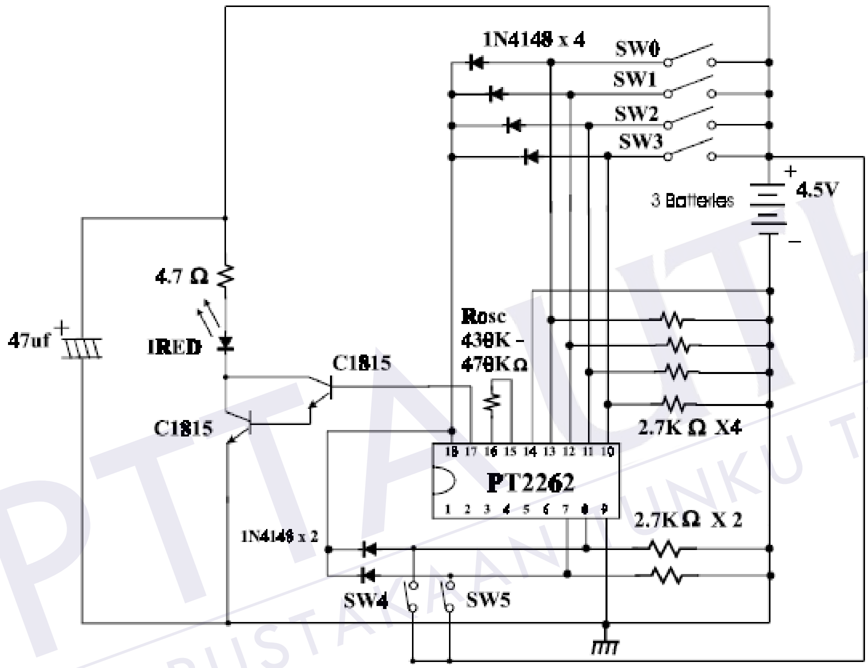


Figure 3.5 IR encoder

3.2.3 Decoder design:

A decoder is combinational logic circuit that essentially performs a “reverse” of encoder functions. A decoder is a logic circuit that accepts a set of inputs that represents a binary number and activates only the output that corresponds to the input number. In other words, a decoder circuit looks at its inputs, determines which binary number is present there, and activates the one output that corresponds to that number

; all other outputs remain inactive. In its general form, a decoder has N input lines to handle N bits and form one to 2^{N} address lines to indicate the presence of one or more N-bit combinations. Fig 3.6 shows the IR decoder.

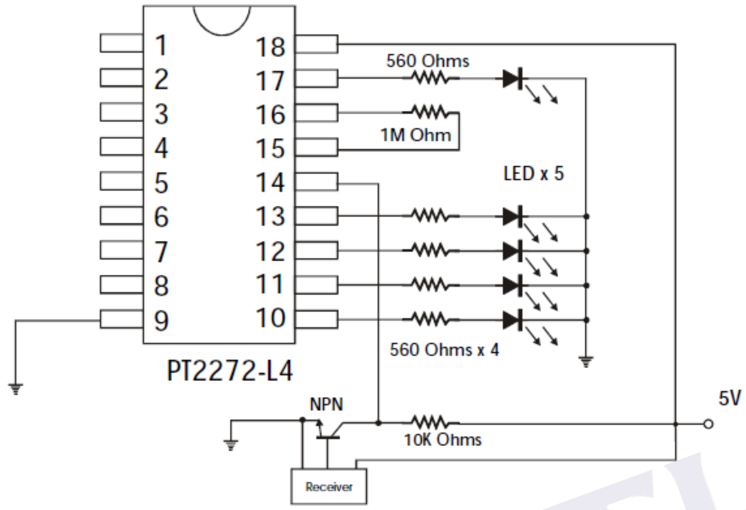


Figure 3.6 Remote control Decoder

3.3 Ultrasonic Transmitter design

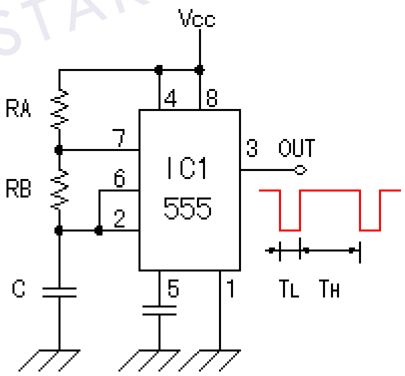


Figure 3.7:Control Pulse Generator

IC1 inFigure 3.7 is the oscillation circuit to control the sending-out time of the ultrasonic pulse, fi. The circuit is the same as the ultrasonic range meter but the value of the resistors and the capacitors are changed. The oscillation frequency is the same.

The time of the oscillation pulse can be calculated by the following formula. Actually, with the error of the parts, it is different from the calculation a little.

The condition : RA = 1M-ohm, RB = 15K-ohm, C = 0.1μF

TL = 0.69 x RB x C
= 0.69 x 15 x 103 x 0.1 x 10-6
= 1 x 10-3
= 1 msec

TH = 0.69 x (RA + RB) x C
= 0.69 x 1015 x 103 x 0.1 x 10-6
= 70.0 x 10-3
= 70 msec

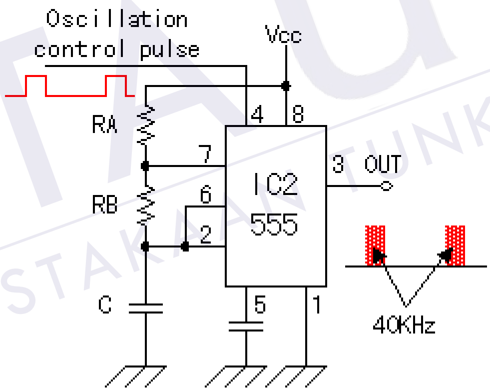


Figure 3.8: 40Khz Pulse Generator

IC2 in figure 3.8 is the circuit to make oscillate the ultrasonic frequency of 40KHz. Oscillation's operation is same as IC1 and makes oscillate at the frequency of about 40 KHz. It makes RB>RA to bring the duty(Ratio of ON/OFF) of the oscillation wave close to 50%. The frequency of the ultrasonic must be adjusted to the resonant frequency of the ultrasonic sensor. Therefore, I am made to be able to adjust the oscillation frequency by making the RB the variable resistor (VR1). The output of IC1 is connected with the reset terminal of IC2 through the inverter. When the reset

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